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Planning, Implementation, and History of the First 5 Years of Operation of the Craig, Alaska, Pool and School Biomass Heating System—A Case Study

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Cover: (upper left) cedar chips from fuel bin with moisture content of 40 to 60 percent; (lower left) fuel bin being loaded during commissioning on May 1, 2008; (right) end view of the Craig boiler building.

Abstract:

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A wood-based energy project in Craig, Alaska, to heat the community's aquatic center and two of its schools was the first such installation in Alaska to convert from fossil fuels to a renewable energy source. Initial interest in the project started in 2004. The system came online in April 2008. This report provides an overview of the new heating system's history, including a review of fuel costs during the study period; background information about the climate and wood resources in the region; initial conception, design, tendering, and construction; and a 5-year summary of operating problems and financial performance. The report will provide information to assist others interested in conversion to renewable wood-energy systems.

Keywords: Biomass, wood energy, district heating.

Contents

Introduction

In the first decade of the 21st century, the cost of petroleum-based energy products was increasing, and individuals and organizations started to focus on lower cost alternative-energy products. Figures 1 and 2 display the national trends for propane (liquefied petroleum gas) and fuel oil, respectively, for the years 1991 to 2012, based on data reported by the U.S. Department of Energy's Energy Information Agency (EIA). The price of both products after delivery to southeast Alaska is consistently higher than these reported U.S. average values. Figures 3 and 4 display the data for 2000 to 2012, which, after least-squares analysis, include the smoothed straight-line fit for the raw EIA data. The R^2 values for the smoothed (fitted) line are 0.95 for propane and 0.90 for fuel oil. Nationally, the average initial price of propane during this period was $1.50/gallon, and it increased at a rate of $0.152 per year. The average national fuel oil price was $1.90/gallon and its annual rate of increase was $0.223. For a rural community such as Craig, located on Prince of Wales Island in southeast Alaska, fuel costs in July 2004 were $1.72/gallon for fuel oil and $1.46 for propane (Miles 2004). Figure 5 compares the Craig fuel oil price and the EIA national averages from 2004 to 2009.

Evolution of the Craig System

In 2004, Craig City Administrator Jon Bolling noted that the cost of fuel to heat the city's Aquatic Center had been going up. Many years earlier, the city had chosen propane to heat the facility because its price was relatively stable, and a local fuel dealer was willing to offer a discount.

Given the increasing price of propane and the prevailing view that prices would continue to rise, the city contracted with Murray and Associates[1] of Juneau, Alaska, to assess the cost of converting from the propane system to one that used fuel oil. At the suggestion of the Prince of Wales Wood Energy Committee, city administrators also asked Murray and Associates to consider the costs and benefits of converting to some form of wood-energy system. The contractor stated that, although they were not familiar with wood-heating systems, such a conversion appeared promising (Murray and Associates 2004).

Table 1 presents statistics that outline the fuels and levels of usage that existed in 2004. In that year, three municipal buildings in Craig were being heated with fossil-fuel systems. At the Craig Aquatic Center, the swimming pool water and the rooms that housed the pool and weight room were heated by propane. The initial effort focused on a system to replace the propane used in the pool building.

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[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

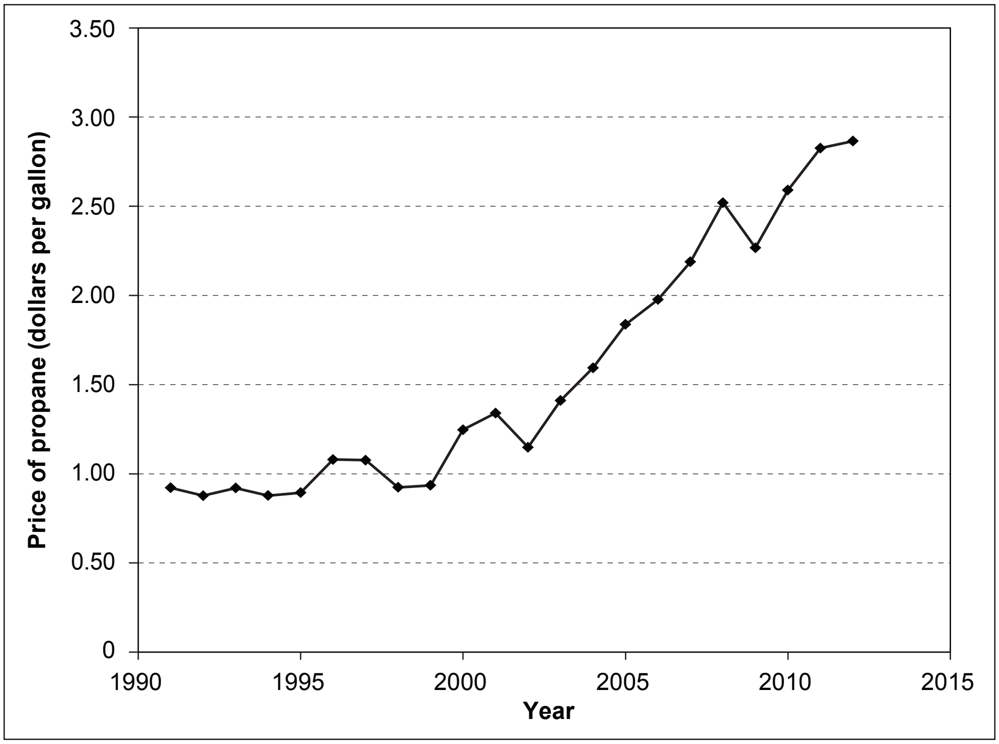

Figure 1—U.S. average price of propane reported by the Energy Information Agency for heating seasons 1991 to 2012.

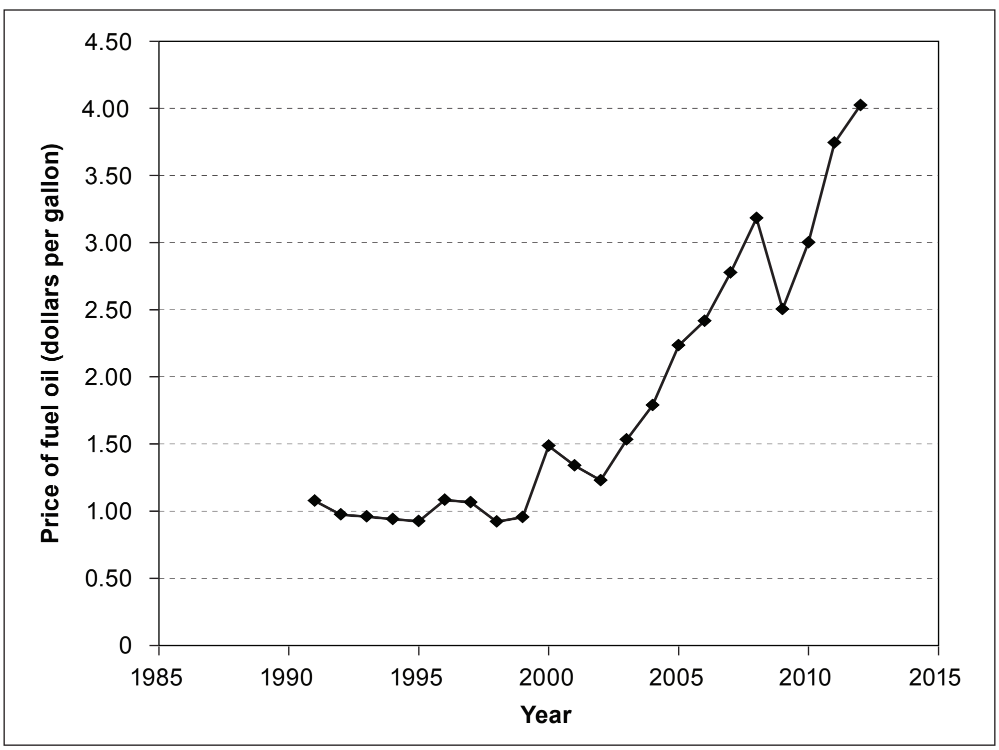

Figure 2—U.S. average price of fuel oil reported by the Energy Information Agency for heating seasons 1991 to 2012.

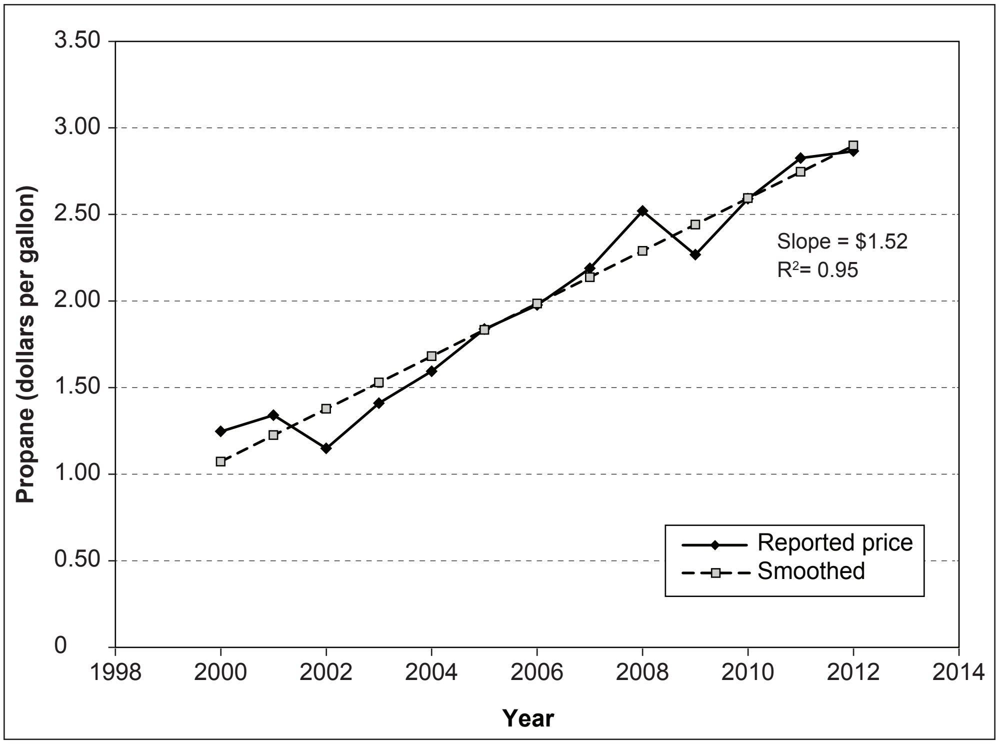

Figure 3—Annual cost of propane (per gallon) during the period 2000 to 2012, based on national-level Energy Information Agency data.

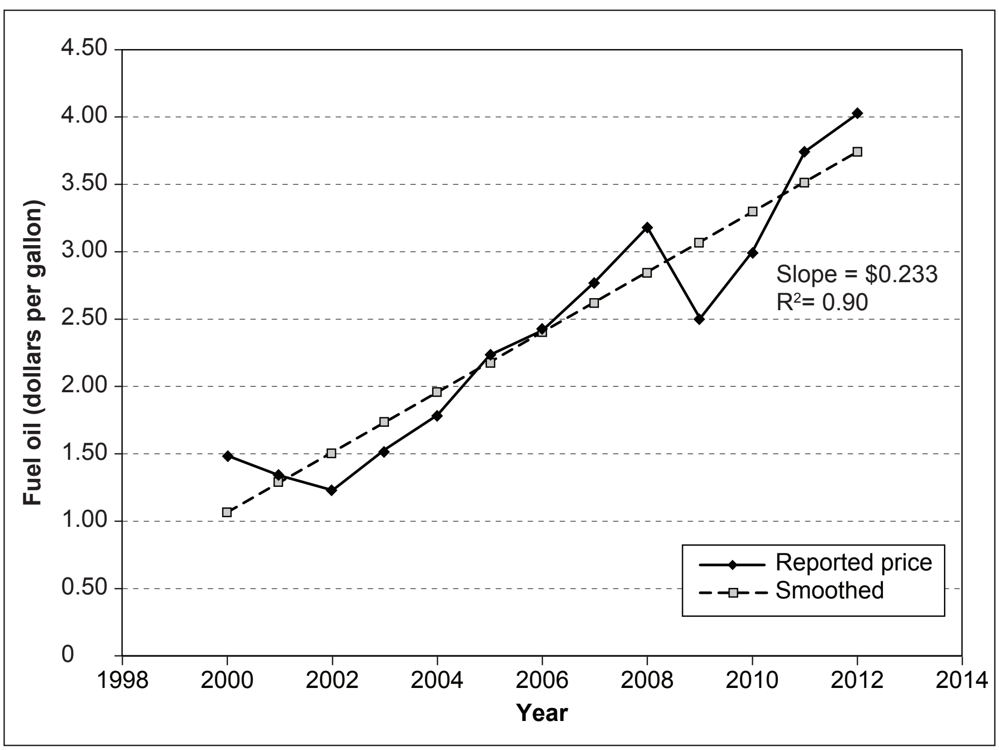

Figure 4—Annual cost of fuel oil (locally referred to as diesel) during the period 2000 to 2012, based on national-level Energy Information Agency data.

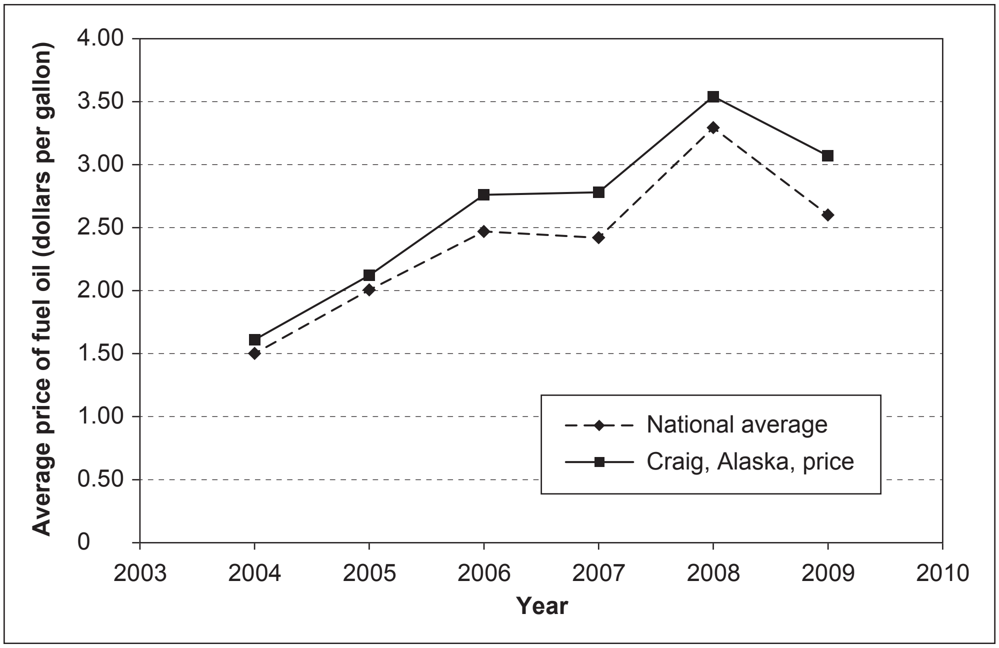

Figure 5—A comparison of fuel oil costs in Craig, Alaska, with the Energy Information Agency-based national average.

As the project proceeded, additional space in the elementary and middle schools was also reviewed for inclusion in the project (table 1). Full conversion of all fossil fuels to renewable energy sources was projected to replace 39,000 gallons of propane and 15,940 gallons of fuel oil (known locally as diesel) each year.

Based on encouragement from Murray and Associates, city officials contacted the Alaska Energy Authority (AEA) for assistance with a second feasibility study that focused on renewable wood-based energy systems. T.R. Miles Technical Consultants, Inc., of Portland, Oregon, was retained to evaluate the technical and economic feasibility of converting the heating system from propane to one using some form of renewable wood energy. The Miles (2004) report also concluded that although the system to replace the pool system was economically feasible, adding the heat load needed by the school represented an opportunity to save additional funds. A biomass heating system that would serve both the pool and the schools was estimated to require 608 tons of fuel annually (Miles 2004). Cordwood and wood chip systems were considered. The study recommended installation of a wood chip system with a capacity of 1.2 million British thermal units per hour (Btuh) and a total capital cost between \$400,000 and \$633,000. By summer 2005, the cost of fuel oil had doubled, making conversion to a biomass-fueled system even more attractive. Note that the rated capacity of this system is described as a medium-size application (Kofman 2006).

Table 1—Fuel types and usage by municipal buildings in Craig, Alaska, in 2004 (Miles 2004)

Building	Existing fuel	Estimated annual usage	Btus/ gallon	Therms (annual)	Demand average	Source
		Gallons			*Btuh*	
Aquatic center	Propane	39,000	91,600	35,724	890,000	Murray and Associates (2004)
					850,000	Miles (2004)
Middle school	Fuel oil	11,000	140,000	15,400	400,000	Estimated
Elementary school	Fuel oil	4,940	140,000	6,916	200,000	Estimated
School subtotal	Fuel oil	15,940		22,316	600,000	

Btus = British thermal units.
Btuh = British thermal units per hour.

Sources of Fuel, Projected Life, and Sustainability of Biomass Supply

City officials were now faced with a new set of issues, many of which were outlined by Maker (2004). The first involved selecting the form of fuel that would be used by the system. Additional concerns were the sustainability of supply and the service life of the installed system.

Craig is surrounded by the Tongass National Forest, which is administered by the U.S. Forest Service. Other landowners in the area include the State of Alaska and Sealaska Timber, a Native corporation created under the Alaska Native Claims Settlement Act.

Local economies on Prince of Wales Island are based on fisheries, forest products, and tourism. One medium-sized sawmill and several smaller ones are located within a 10-mile hauling distance from the site in Craig to be heated (Kilborn et al. 2004). City officials were concerned about the sustainability of a biomass fuel supply, but during visits to Viking Lumber Company in Klawock, a town about 8 miles north of Craig, they learned that the mill produced more than 60,000 tons of residual products annually (chips and sawdust) that potentially could be used as fuel. In comparison, the estimated annual requirement of 608 tons (Miles 2004) was seen as minimal in relation to the volume produced by the mill and other possible sources. Craig officials also decided that even if the mill closed and the harvest of timber ended, enough existing wood waste was available to feed the new heating system throughout its estimated lifespan of 25 to 30 years.

After reviewing the forms of available biomass, Craig officials selected sawmill chips as the most desirable fuel. The movement of chips from the mill, using a truck modified for delivery, was a simple operation. Seven-ton units of chips could be delivered and loaded directly into a fuel storage silo. Numerous auger systems could be designed to feed the chips from the silo to the burning unit.

Special Wood Fuel Problems in Southeast Alaska

There are two conventions used to report the moisture content (MC) of forest products. Wood technologists concerned with solid-wood products calculate MC in relation to the oven-dry weight of the material. Under this system, the reported MC can be in excess of 100 percent (dry basis). Pulp and paper technologists and combustion engineers, however, calculate MC in relation to the initial weight of wood material and water in the sample, and refer to this as total weight basis, or wet basis, so that 100-percent dry basis is equal to 50-percent wet basis (Bowyer et al. 2003, Wilson 2010). These cited reports contain additional information relative to wood moisture and the impact of this value on energy values of biomass materials.

Southeast Alaska is located in the temperate rain forest of the Pacific Northwest region of the United States. Rainfall in the region can range from 60 to 250 inches annually (NCD 2015). Wood is a hydroscopic material that is constantly exchanging moisture with the surrounding environment (Bowyer et al. 2003). About half the weight of a living tree is that of its water content. Nicholls and Brackley (2009), in a study to determine drying rates of young-growth Sitka spruce and western hemlock house logs harvested from Prince of Wales Island, determined that nearly freshly cut Sitka spruce and western hemlock had moisture contents of 88.3 percent and 100.6 percent (oven-dry basis), respectively, or 46.9 percent and 50.1 percent (total weight or wet basis).

When trees are felled, they immediately start exchanging moisture with the environment. After cutting, the wood starts losing moisture and will eventually come to equilibrium with the atmosphere. Using NCD (2015) data for 2007 and methods outlined in Simpson (1998), Nicholls and Brackley (2009) calculated the annual equilibrium moisture content for the Ketchikan Airport, an area comparable to Craig, as 20.1 percent (oven-dry basis) or 16.7 percent (total weight/wet basis). The MC of delivered chips from freshly cut logs will vary depending upon how long the logs were decked prior to milling and to methods used to store chips. The exact MC of chips in exposed piles will be influenced by the amount of rainfall and snow that has accumulated from the date of production to the time the chips were moved to the storage silo.

Engineers retained by the City of Craig and the AEA were aware of the high MC of wood fuels in southeast Alaska, specifically in Klawock. The MC of mill samples was measured by R&M Engineering. Based on fresh weight, uncovered hog fuel had a 67-percent MC, covered hog fuel was at 56 percent, cedar chips at 48 percent, and sawdust at 37 percent. A request for proposals was issued for the boiler in 2005 that specified 50-percent MC fuel with the provision to burn "secondary wood fuel" at 70-percent MC. The boiler supplier was not required to provide fuel drying equipment. Several suppliers responded that they would not bid unless the moisture content was 30- to 40-percent MC wet basis (Miles 2004).

Initial Design Phase

A request for proposals (RFP) was issued in 2005 for the boiler system. Chiptec® Wood Energy Systems of Williston, Vermont, was the only bidder. This company's boiler has a two-stage burner/gasification system. The system is extremely clean-burning and meets Environmental Protection Agency emission requirements.

In spring 2006, the City of Craig applied for and received funding to proceed with the design and engineering of an automated wood-chip district heating system. Funding to support this phase of the project was supplied by the city, the Forest Service, and the AEA. Table 2 gives the sources and amounts of funding for the design phase. The order for the boiler was placed in May 2007.

Table 2—Funding for wood-energy system design

Source	Amount
	Dollars
City of Craig	40,000
USDA Forest Service	30,000
Alaska Energy Authority	30,000
Total	100,000

Delivery of the system was scheduled for October 2007. It was planned for the boiler to be operational by December 2007 or January 2008, but installation and setup was not completed until early April 2008.

R&M Engineering of Ketchikan, Alaska, and CTA Associates of Missoula, Montana, were awarded contracts for design and engineering. The city specified that the design would be a district hot-water system to meet the needs of the swimming pool and the elementary and middle schools. Also specified was that the system would include a chip-drying capability.

The engineering firms designed the distribution component so that hot water could be circulated to existing underground insulated pipes. Heat exchangers were used to interface with the existing piping, and a control system was designed so that in the event of a falling water temperature from the biomass-fueled unit, the existing propane unit would function as a backup to the new chip-fired system.

After alternative drying methods were evaluated, the boiler vendor was asked to supply a modified moving-floor chip bin. The purpose of the unit was to reduce excess moisture to the 50-percent MC guaranteed by the boiler supplier. This "in-floor" dryer has been used in Europe. The boiler supplier guaranteed the unit's ability to burn at 50-percent MC. Their bid stated that "in order to utilize high-moisture-content fuels in the gasifier, the gasifier box must be hot enough to evaporate all of the moisture in the fuel and create the pyrolysis gas from the biomass itself." In its proposal, Chiptec noted, "…this system has been installed in several other locations, which have reported the ability to utilize fuel with a MC of 60 percent or more with no performance degradation" (Petersen 2010).

Heat loads were recalculated with the additional drying load, and system capacity was increased to 4 million Btuh with allowance for possible future heat customers. Even then, the boiler would be operating at less than 50 percent of its capacity; such boilers operate most efficiently at 80 percent of rated capacity (Miles 2015). The fuel storage, building construction, and heat distribution were all upgraded. The design and engineering firm estimated total costs for the system to be $1.2 million. Funding for the construction phase of the project was supplied by the AEA, the National Resources Conservation Service, and the Forest Service. Funding supplied by AEA was in part a grant and the remainder from its Power Project Loan Fund. Amounts and sources of funding for construction are presented in table 3.

Table 3—Funding to construct the system

Source	Amount
	Dollars
Alaska Energy Authority	300,000
Denali Commission	300,000
National Resources Conservation Service	50,000
USDA Forest Service	117,000
Loan from Alaska Energy Authority	500,000[a]
Total	1,267,000

[a] Loan from Alaska Energy Authority's Power Project Loan Fund (in later years, a grant of $161,000 was received to pay the outstanding amount).

Tendering

The project went out to bid for construction. Two responses were received. Proposed costs for the system ranged from $1.7 to $2.3 million. Given available loans and grants, Craig needed to find an additional $1.0 million to proceed with construction and purchasing. Two actions were taken by the city to address this issue. First, the city council voted to assume responsibility and act as contractor for the project. By assuming this role, the city reduced the deficit amount to about $400,000. The city then was awarded a $500,000 line of credit from a local bank.

Phase I—Construction

The City of Craig hired a project manager to oversee construction of the facility. The city administrator functioned as the controller and was responsible for the receipt of grant funds and payments for services. Each phase of the project was designed as a separate small contract and tendered to local businesses.

Figure 6 shows the location of the system within the center of the community. Ceremonial groundbreaking was held in August 2006. Site preparation took place in fall 2006. Actual construction of the building to house the equipment began with pouring of the concrete foundation in spring 2007. Figures 6 through 9 provide information on the stages of construction.

Figure 6—Location of the wood-fired boiler system, Craig, Alaska.

Figure 7—Concrete foundation of the Craig boiler system.

Figure 8—Front view of the Craig boiler building.

Figure 9—End view of the Craig boiler building.

Phase II—Startup and Initial Testing

In anticipation of startup, a supply of fresh wood chips, blown directly from the chipper to the delivery truck, was furnished by Viking Lumber. At the time, the chip bin was only partially loaded.

In mid-April 2008, Chiptec owner John Tomasi arrived to oversee final installation and initial firing of the boiler (fig. 10), which had a control system that included two computer systems (fig. 11). One system controlled the actual combustion process by regulating oxygen flow to the boiler as well as auger feed rates. The second computer controlled the pumps in the hot-water delivery system and the air flow to the wood-drying system. Calibration of the computers and their adjustment to local operating conditions was a major part of the startup effort.

On April 15, 2008, the feed augers were started and the fuel was ignited to bring the system online for 24 hours. At that time, a second load of wood chips was delivered to the facility (figs. 12 and 13). This load of chips, however, was taken from the exposed outside storage pile which, as expected, had a high (40 to 60 percent) MC. As startup progressed, T.R. Miles instructed personnel in the operation of the dryer and in the use of a microwave oven (ASTM 2013) to determine fuel MC (figs. 14 and 15).

Given the extreme moisture content of the second load of fuel, it was impossible to maintain the fire in the boiler. Fortunately, the boiler had produced a sufficient

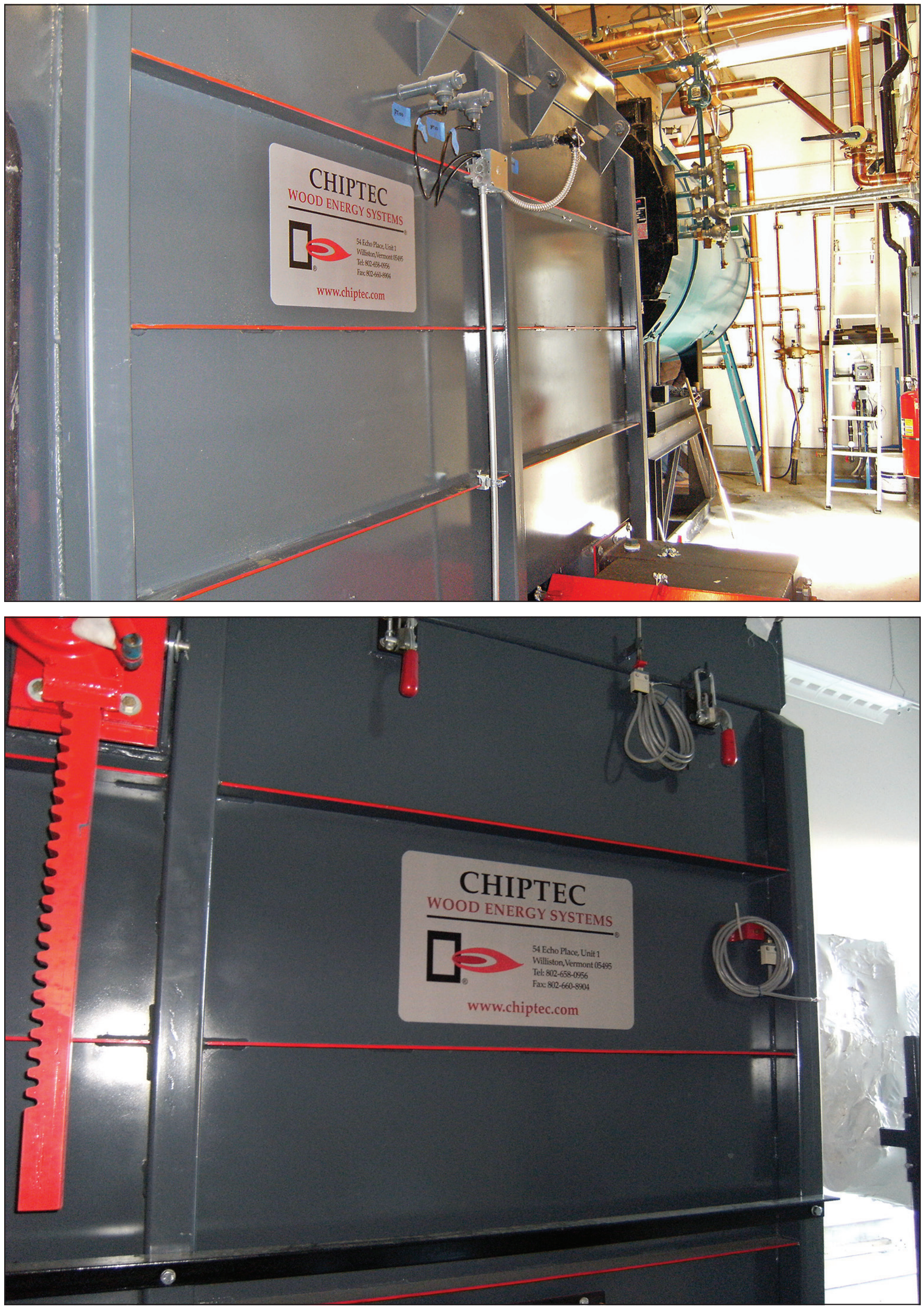

Figure 10—Views of the Chiptec® boiler system in Craig, Alaska.

Figure 11—Boiler control system.

Figure 12—Loading the fuel bin during commissioning on May 1, 2008.

Figure 13—Fully loaded fuel bin, May 2, 2008.

Figure 14—Cedar chips from fuel bin with moisture content of 40 to 60 percent.

Figure 15—Equipment for determining moisture content using ASTM E1358 (microwave method).

water temperature to support activation of the "in-floor" drying system. After a day of drying, the chips were conditioned to a moisture level that would continuously maintain a fire. By the end of the week, the system was maintaining a constant water temperature and it was possible to turn off the propane heaters in the pool area. The diesel boilers in the schools were adjusted after the renewable-energy system came online. At this point, the Craig system was fully operational but was in use only until the end of May 2008 when the schools were closed for the summer. Under the reduced heat requirement of the summer months, the boiler could not be operated at peak efficiency (80 percent of capacity) thus was shut down for the summer.

Final Construction Costs

The construction phase was reasonably straightforward, despite challenges created by the need to ship all material and equipment to Craig by barge. To those who live in the region, this is a well-known problem. Contractors and equipment vendors familiar with the region recognize a need to factor in the added shipping costs and time delays associated with this mode of transportation. For contractors and equipment suppliers from the lower 48 states who are not familiar with the region, it provides a learning experience.

Table 4 presents the budget and actual costs for each of the components of the construction process. The increase in cost for concrete and foundation walls was unexpectedly high owing to an increase in the cost of rebar used for reinforcement. The city was able to reduce some costs in the mechanical and contingency items by performing tasks "in-house" as opposed to contracting for services. In total, actual costs of construction came in 4 percent below budgeted levels.

Table 4—Budgeted amounts and actual costs for each of the components of the construction process

Construction costs	Budget	Expenditures
	- - - - - - *Dollars* - - - - - - -	
Engineering	15,000	23,292
Labor	220,000	209,514
Concrete foundation and walls	65,609	122,820
Building	53,936	108,414
Boiler	385,867	359,495
Mechanical	660,000	577,042
Contingency	72,521	10,313
Total	1,522,933	1,410,890
Outstanding invoices as of 5/31/2008[a]		46,165
Construction total		1,457,055

[a] Cost of independent contractors to troubleshoot issues with boiler during initial startup period. These costs were paid from budgeted amounts.

Early Lessons Learned

About 2 weeks after startup, a local contractor accidentally toppled a power pole that supplied electricity to the facility. After power was restored, the outage was found to have caused the boiler's computer systems to reset to the manufacturer's specifications, thus the system needed to be reprogrammed to the optimal onsite operating conditions. Because power outages are not uncommon in southeast Alaska, a battery backup system was installed to prevent this from re-occurring.

Also discovered was that when loads were low and heat was directed to the drying floor for long periods, the in-floor drying system was overdrying the fuel. Trial-and-error methods during the first month of operation revealed that the drying system could reduce fuel MC to a level of 10 percent. In general, small-capacity chip burning systems are designed to use fuel at between 20- to 40-percent MC (total weight basis) (Kofman 2006). Moisture contents below this level potentially can cause a number of problems. Augers grind overdried wood into small particles and dust. Dust explosions can then result from an electrical spark, a common problem in many forest products manufacturing systems, not just boiler systems. In addition, excessively dry fuel can "flash burn" and fail to maintain a constant heat source. Although identified during the initial start-up, this overdrying of fuel presented a major challenge for the boiler's future operation. The challenged resulted from the fact that no provision was made for continued instruction in the use of the floor drier or the boiler. These problems could have been avoided by better planning and budgeting for startup, periodic inspection, and training.

Lessons Learned During First Year of Operation

After initial startup and less than 2 months of operation in spring 2008, the first extended period of operation began in September 2008 and ran through 2009. Additional operating problems were identified during this period. During the first full year, the city employed an independent engineer to troubleshoot operation of the boiler. Although Craig could show a cost savings from the use of wood chips, many questions remained about the efficiency of the unit. The engineer classified operational problems into four areas:

- Problems associated with the wood-chip supply or fuel quality.
- Problems with the boiler itself.
- Problems with the fuel-oil boilers in the school running when they should not be running.
- Operator error.

Fuel Quality Problems and Solutions

With respect to the wood-chip supply, one problem was contamination of the fuel. The chips delivered to the site were unscreened and contained large pieces of wood. Most of the larger pieces could be removed by hand, but often they turned crosswise in the auger system and interrupted the flow of chips to the burn box, resulting in a drop in heat output. At one point, a large piece of wood that had jammed the feed auger led to shearing of the auger shaft.

During winter months, wood chips from the mill's outdoor storage pile were often frozen together into solid blocks. Some of these blocks were up to a square meter in size. These blocks of unthawed chips would "bridge" the feed system at the bottom of the bin and jam the fuel flow. When the in-floor drying system was put on high to help eliminate ice, it consumed so much heat that the water temperature in the boiler would drop.

Solutions to these fuel quality problems included both short-term fixes and planned modification to the fuel supply systems, both at the mill and at the boiler site. First, use of chips directly from the chipper solved much of the ice problem. Second, in almost every forest products production system that uses chips (pulp and paper mills, particle board plants, etc.), a critical phase in the production process is the screening of chips to create a uniform product that will flow through production without plugging the feed system. Screening can be done either at the point of chipping or at the boiler site. Screening was discussed in the early planning of the boiler. A decision was made to screen and dry fuel at the mill instead of at the boiler. In a region in which there is a competitive market for fuel chips, it is a simple matter for the purchaser to specify chip size requirements in a procurement contract, or to install a screening system at the boiler site to obtain material that meets specifications. But this is not the case in southeast Alaska. The second aspect of the problem, freezing of chips, is a little more complex. One solution is storage of the fresh chips under cover to prevent accumulation of snow and rain on the pile. This is a partial solution, but if there is sufficient moisture in the fresh chips in extremely cold climates, they will freeze without some form of heating. As a temporary solution, chips shipped to Craig were loaded into the truck directly from the chipper.

Initial Installation Problems and Solutions

During the last quarter of 2008 and early 2009, analysis of fuel usage revealed that the elementary school's diesel boiler was actually running regardless of the level of operation of the chip boiler system. The system log book indicated that the temperature of the hot water return line was in fact higher than the delivery line.

During summer shutdown in 2009, the in-floor drying system was found to have been “stealing” heat from the school hot-water feed line. This installation flaw reduced the temperature of the hot-water feed to a level that caused activation of the school’s diesel-fueled boiler. The control system assumed that the biomass boiler was off-line or down, and turned on the diesel boiler to compensate for the reduced feed water temperature.

When the boiler was shut down at the end of the 2008–2009 school year, the burn box grates were found to have been damaged by too much ash buildup. The buildup of ash on the grates impeded precise air flow up through the grates and resulted in substandard operation of the burner. The ash buildup resulted from the use of dirty fuel as well as inadequate grate cleaning (Miles 2015). Also during the down-time inspection, an air leak was discovered in the primary burn chamber; as a result, the gasifier (second stage of the burn process) had not been operating efficiently. The leak and resulting excessive air caused considerable damage to the fire brick that had to be repaired (Bolling 2009).

Although these problems have been referred to as boiler installation and fuel problems, they may have resulted from inadequate training of the new system’s operators, as discussed below.

Operator Error/Need for Training

The initial estimate of staff time needed to operate the new system was about 45 minutes per day, with occasional extra hours for routine cleaning and maintenance. But operation and maintenance typically takes 10 to 12 hours per week for an installation of this kind. The boiler as delivered had an automated ash removal system, which was assumed to reduce the amount of required maintenance.

In reality, the school district’s maintenance person spent several hours each day at the boiler site. During some days, up to 4 hours were spent at the site. One of the reasons for excessive maintenance time was insufficient training of the staff and a need for unsupervised on-the-job training.

Tasks initially assigned to the maintenance person included daily logging of temperatures and other operating characteristics of the system. Removal of ash from the ash bin was scheduled as a weekly activity. Cleaning of the grates in the burn chamber and removal of the sawdust from the air channels under the chip bin, which were parts of the in-floor drying system, were defined as periodic activities to be done as necessary. In retrospect, it became obvious that too much reliance had been placed on the automated ash removal system. Failure to schedule routine cleaning of ash from the firebox contributed to some of the operational problems with the total system.

Problems identified during the first complete year of operation have been corrected. The staff has been properly trained to maintain the system. Viking Lumber was asked to supply clean chips directly from the production process to ensure minimum levels of contamination and moisture content. After August 2009, the boiler was expected to operate at maximum efficiency and meet earlier projections of its costs and benefits. However, there has been a continuing problem of dirt in the fuel and resulting high levels of ash. The dump truck used to haul fuel was also used to haul gravel products. Failure to clean the dump truck prior to hauling chips resulted in contamination. The high levels of dirt and resulting ash has made it necessary to conduct extensive maintenance at the end of each heating season.

Analysis of the Costs and Benefits of the System

A cursory look at available financial data indicates that the new system has in fact reduced fuel costs for the City of Craig. The true potential of the system and a complete financial analysis of benefits, however, has been confounded by problems inherit in the startup process (the first complete year of operation), a situation that is not uncommon with new technology.

Before we review the specific costs and benefits of the Craig system, we should consider the economics of non-renewable energy from 2000 to 2012. We chose this period because it exhibits trends in Craig's energy costs both before and during the periods leading up to the decision to build the system. It also reflects what actually happened during the early years of operation.

Nonrenewable energy prices, 2000–2012—

From 2000 to 2012, the average annual increase in the price of propane was $0.152 per gallon (fig. 3), while the average annual increase in the price of fuel oil was $0.223 per gallon (fig. 4).

Table 5 compares the quantity and costs of fuel and electricity needed to power the new heating system. The wood chips used during the startup period were supplied by Viking Lumber Company of Klawock, Alaska. Dates available for 2010 to 2015 are reported.

Table 6 estimates savings resulting from the new system by calculating what annual propane and fuel-oil costs would have been at then current prices, based on preconversion usage levels (Miles 2004), had the new system not been installed. Some of these savings have been offset by increased costs for operating and maintaining the boiler.

Representatives of the City of Craig have expressed a high degree of satisfaction with the system. First, they have noted that savings made additional funds

Table 5—Sources and costs of energy used by the Craig Aquatic Center, Elementary School, and Middle School, 2009 to 2014

Fiscal year	School fuel oil			Aquatic center propane			Added electricity to run new boiler unit			Chips			Total cost
	Gallons	*Dollars per gallon*	*Cost in dollars*	*Gallons*	*Dollars per gallon*	*Cost in dollars*	*Kilowatt-hours (Kwh)*	*Dollars per Kwh*	*Cost in dollars*	*Green tons*[a]	*Dollars per ton*	*Cost in dollars*	*Dollars*
2009	15,012	3.00	45,110	10,736	1.58	16,918							
2010	2,999	3.04	9,110	13,222	2.13	28,181	55,140	0.13	7,168	924	30	27,720	72,180
2011	1,987	3.71	7,373	15,243	2.51	38,209	54,382	0.14	7,613	1218	30	36,540	89,736
2012	3,658	3.86	14,122	10,010	2.38	23,829	45,810	0.15	6,872	1169	30	35,070	79,893
2013	2,380	5.00	11,898	6,821	2.48	16,926			8,657	1302	30	39,606	77,087

Source: City of Craig.
[a] Volumetric ton in a dump truck with an estimated load of 7 tons (cubic content of dump body not specified).
[b] Amounts reported by City of Craig included extra propane used in refractory work. The reported amount of 1,500 gallons is not included above. Wood-chip boiler was also direct-fired using propane while repairs were made.

Table 6—Estimated annual savings based on preconversion fuel usage (Miles 2004) at current-year prices

	Estimated preconversion propane usage and cost			Estimated preconversion fuel-oil usage and cost			Total estimated preconversion cost	Annual cost	Annual savings
	Gallons	*Dollars per gallon*	*Cost in dollars*	*Gallons*	*Dollars per gallon*	*Cost in dollars*	- - - - - - - - - -	*Dollars*	- - - - - - - - -
2010	39,000	2.13	83,070	15,940	3.04	48,458	131,528	72,180	59,348
2011	39,000	2.51	97,890	15,940	3.71	59,137	157,027	89,736	67,291
2012	39,000	2.38	92,820	15,940	3.86	61,528	154,348	79,893	74,455
2013	39,000	2.48	96,720	15,940	5.00	79,700	176,420	77,087	99,333
2014	39,000	2.20	85,800	15,940	4.05	64,557	150,357	80,989	69,368

available to the school system. Other sentiments include pride in installing a system that uses local resources, keeps dollars in the community, and reduces the dependency on foreign oil. Officials also reported that, although the system is located in the center of the community, it has minimal emissions to the environment. People living nearby describe the system as clean-burning and not adversely affecting local air quality.

Craig's new district heating system represents the first such project in Alaska to convert from fossil fuels to a renewable biomass energy source. The system has now been in use for five complete seasons and appears to be on track to provide, at minimum, a 20-year payback period. The ultimate payback period and return on investment will be subject to future changes in the price of fossil and biomass fuels. In summary, annual savings in fuel costs for the first 5 years of operation range from $59,000 to $99,000.

Craig city officials said that they were highly satisfied with the system but readily admit that installing and operating it has been a "learning process." This case study has been prepared to assist those who are considering similar projects. City Administrator Jon Bolling affirmed that because the new system keeps jobs and spending within the community, as opposed to supporting foreign sources of oil, the system would be a success even if it merely broke even.

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Feet (ft)	.305	Meters
Square feet (ft^2)	0.093	Square meters
Cubic feet (ft^3)	.0283	Cubic meters
Cubic yards (yd^3)	0.765	Cubic meters
Acres (ac)	0.405	Hectares
Pounds (lbs)	0.454	Kilograms
Tons (t)	0.907	Tonnes or megagrams
Gallons (gal)	3.78533	Liters
British thermal units (Btu)	0.000293	Kilowatts
British thermal units (Btu)	1.05505	Kilojoules

Tree Species Identified in This Report

Common name	**Scientific name**
Alaska yellow-cedar	*Callitropsis nootkatensis* (D. Don) Oerst. ex D.P. Little
Black spruce	*Picea mariana* (Mill.) Britton, Sterns & Poggenb.
Red alder	*Alnus rubra* Bong.
Sitka spruce	*Picea sitchensis* (Bong.) Carrière
Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
White spruce	*Picea glauca* (Moench) Voss

Literature Cited

ASTM. 2013. Standard test method for determination of moisture content of particulate wood fuels using a microwave oven. ASTM E1358-97(2013). West Conshohocken, PA: ASTM International. http://www.astm.org/Standards/E1358.htm. (January 25, 2016).

Bolling, J. 2009. Personal communication. City administrator, PO Box 725, Craig, AK 99921.

Bowyer, J.L.; Shumulsky, R.; Haygreen, J.G. 2003. Forest products and wood science—an introduction. 4th ed. Ames, IA: Wiley-Blackwell. 553 p.

Kilborn, K.A.; Parrent, D.J.; Housley, R.D. 2004. Establishing sawmill processing capacity for Tongass timber. Res. Note PNW-RN-545. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 12 p.

Kofman, P.D. 2006. Quality wood chip fuel. Dublin, Ireland: Council for Forest Research and Development. 4 p. http://www.seai.ie/Renewables/Bioenergy/Quality_wood_chip_fuel.pdf. (August 28, 2015).

Maker, T.M. 2004. Wood-chip heating systems—a guide for institutional and commercial biomass installations. Montpelier, VT: Biomass Energy Resource Center. 91 p.

Miles, T.R. 2004. Recommendations for the City of Craig pool heating project. Report to Alaska Energy Authority.

Miles, T.R. 2015. Personal communication. Engineer/owner, T.R. Miles Technical Consultants Inc., 1470 SW Woodward Way, Portland, OR 97225.

Murray and Associates. 2004. Craig pool cost analysis: propane to fuel oil heating system conversion. Report to the City of Craig. Juneau, AK. [Pages unknown].

National Oceanic and Atmospheric Administration, National Climatic Database [NCD]. 2015. http://www.ncdc.noaa.gov/cdo-web/. [Date accessed unknown].

Nicholls, D.; Brackley, A.M. 2009. House log drying rates in southeast Alaska for covered and uncovered softwood logs. Gen. Tech. Rep. PNW-GTR-782. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p.

Petersen, K. 2010. Craig wood fired boiler—a case study of a renewable energy project. Fairbanks, AK: University of Alaska, Department of Alaska Native and Rural Development. M.A. project report. 68 p.

Simpson, W.T. 1998. Equilibrium moisture content of wood in outdoor locations in the United States and worldwide. Res. Note FPL-RN-0268. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 11 p.

U.S. Department of Energy, Energy Information Administration [EIA]. 2012. Residential propane prices (dollars per gallon). http://tonto.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=W_EPLLPA_PRS_NUS_DPG&f=W. (April 10, 2012).

Wilson, P.L.; Funck, J.W.; Avery, R.B. 2010. Fuelwood characteristics of northwestern conifers and hardwoods (updated). Parrent, D.J.; Funck, J.W.; Reeb, J.; Brackley, A.M., eds. Gen. Tech. Rep. PNW-GTR-810. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 50 p.

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